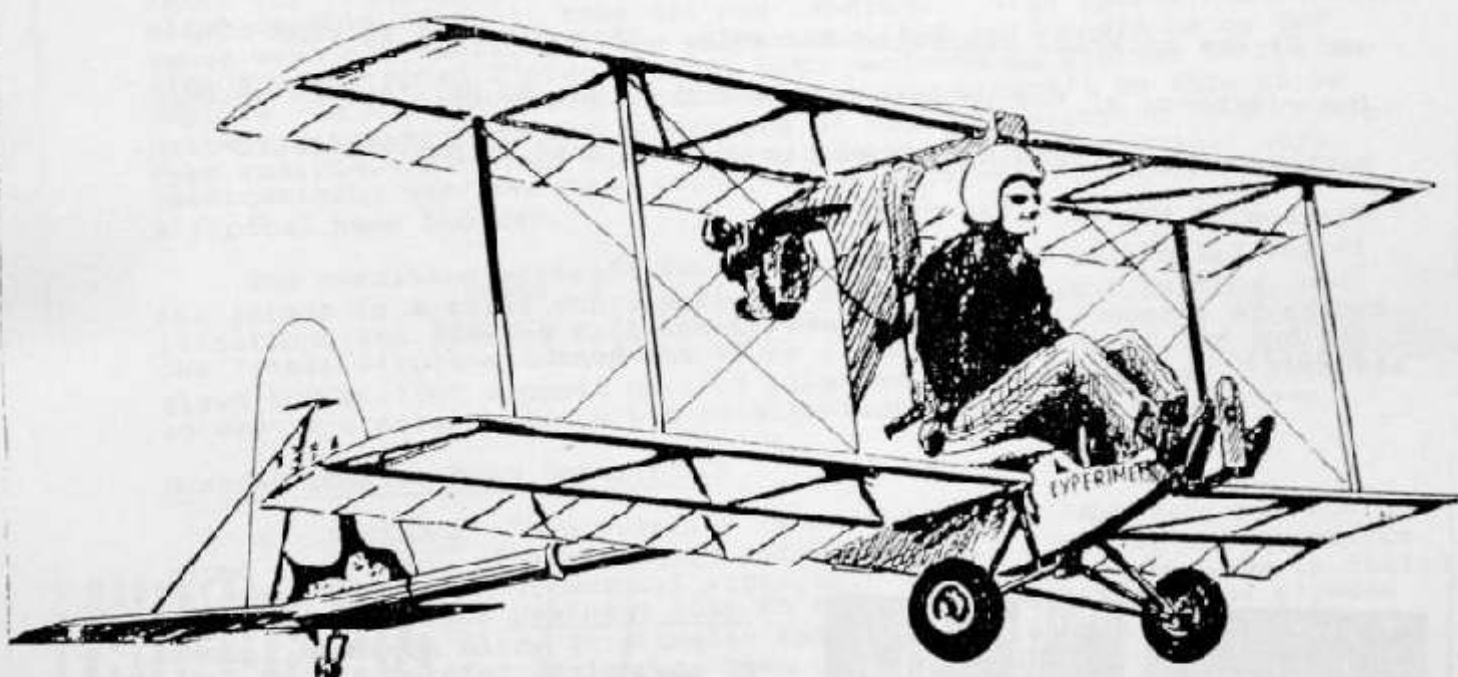


WD-II (WHING DING)

ULTRA-LIGHT BIPLANE



CONSTRUCTION METHODS DESCRIPTION

BY R. W. HOVEY
DESIGNER AND BUILDER

LEGAL NOTES

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R. W. Hovey

3/24/71



World's lightest aircraft?

This build-it-yourself airplane weighs less than its pilot—only 120 pounds. Made of lightweight foamed-plastic panels with an aluminum-tube tail boom, it resembles an early Wright Brothers creation and, in fact, incorporates some of the same basic principles. In place of ailerons, it uses "wing warp" for roll control, just as the Wrights did, and has "plug-in" wing spars borrowed from the World War I French Spad. Its pusher prop is powered by a 15-hp McCulloch kart engine, giving the ship a cruising speed of 50 mph. Though it's not officially established, designer Bob Hovey, an aerospace engineer, believes his flyweight is the world's lightest man-carrying, prop-powered aircraft. Plans are \$10 from R.W. Hovey, Box 1074, Saugus, Calif. 91350.

DESIGN NOTES
and
CONSTRUCTION DESCRIPTION

INTRODUCTION

The Wd-II (Whing Ding) is an ultra-light, single place, single engine, pusher prop sport biplane. The concept was born with the introduction of a new 15 Horsepower, single cylinder, two stroke cycle engine, developed for competition kart racing. The power to weight ratio of this new engine provided for the first time, the performance necessary for minimum man carrying flying machines. The design objectives were to reduce construction time to a minimum and meet the requirements for light weight structure and still produce an attractive airplane capable of short take off and landings. High speeds and extended range were not required. The intent was that this would be an OFF-AIRPORT type sport flying machine with performance similar to Gyro-copters. A further design goal was that the aircraft be able to be quickly disassembled and be capable of being transported in a trailer type vehicle. Although some advance techniques and materials were used, nothing was done that could not be obtained or accomplished by a typical home builder.

The resulting aircraft was designed, fabricated and rolled out of the garage in a three month period. Subsequent flight testing, modifications and drawing refinements took several more months of effort. The little airplane turned out to be a real fun thing to fly and has given the builder a great deal of pleasure and satisfaction. Needless to say it creates quite a bit of attention where ever it is shown.

GENERAL CONSTRUCTION DESCRIPTION

a. FUSELAGE - The fuselage is made from 1/8" Mahogany plywood glued to 1/2 sq. pine stringers and longerons. A closed box structure provides the basic structural strength. The complete fuselage is filled with foam-in-place Urathane foam to stiffen and stabilize the plywood skin. Aluminum Alloy 3" diameter thin wall tubing was used for the tail boom. Careful design has been used to produce the strength to weight ratio for practical boom type construction. A doubler sheet of high strength aluminum alloy is wrapped around the tube at the forward or root end where the bending loads are greatest. Epoxy metal bonding was used to attach the high strength sheet to the tube.

The 6 inch wide fuselage provides an attachment point for the seat, the rudder bar, controls and sockets for the wing spars. The engine is mounted on a reinforced aft extension of the fuselage. The landing beam bolts directly to the underside of the fuselage.

b. WINGS - The wings are made up of four panels, each panel has a front and rear spar made from spruce. The inboard ends of the wing spars plug into rectangular holes in the fuselage. 3/4 inch square pine members space the forward and aft spars 22 inches apart. Wing panel drag/antidrag forces are carried by 3/4 inch square diagonals.

The ribs are hand formed to an airfoil shape from 3/8 inch tubing. A series of holes are drilled both in the front and rear spars. The ribs are inserted thru the holes in the rear spar and are plugged into holes in the front spar. The wing fabric is attached to the trailing edge and is drawn over the top, around the leading edge, and under the bottom side to the rear beam. The tip bows also made of 3/8" aluminum tubing and utilize holes in the beam for attachment. The leading edge is faired in with rigid urathane foam.

There are no ailerons, however roll control is achieved by wing warping much as the Wright Brothers did. The rear flying wires are tied into a pulley such that lateral stick motion raises or lowers the outboard portion of the rear beam. A plastisizer is used with the fabric dope to allow for wing warping flexibility in the fabric.

c. TAIL GROUP - Alternate designs are provided for either foam sheet, covered with epoxy bonded light weight fiberglass cloth type of surface construction, or a conventional pine stick and plywood gusset construction. In either design the horizontal tail is of the one piece (all flying) type. A conventional fin and hinged rudder design if used. The complete horizontal surface is supported on a piano hinge joint attached directly to the tail boom. 1/8" plywood doublers are used at high load points. Aluminum tube struts located in line with the horizontal tail hinge line are used to brace the tail group.

The vertical tail consisting of a fin and rudder may also be made from foam and fiberglass, or wood construction. Cloth hinges are used at the rudder joint. The lower end of the rudder is attached to a steel torque tube extending down thru the tail boom. The rudder control horns and tail wheel are welded to the lower end of this torque tube.

d. MAIN LANDING GEAR - A pair of 6.0" hub by 4.10 tire, wheel assemblies are used. These are commonly used for Kart Racers and incorporate ball bearings. The spring type landing gear strut is fabricated from laminated fir, covered with one layer of polyester fiberglass. Two bolts attach the landing gear assembly to the fuselage. (an alternate steel tube design is included.)

e. PROPELLER - A simplified method was developed for laying out and carving a laminated birch or beechwood prop. Four laminations are bonded with weldwood glue. Details of prop fabrication are included in drawings.

f. ENGINE - The WD-II was designed specifically around the McCulloch 101AA Engine. ALTERNATE ENGINES - Alternate engine and prop drive systems may be worked out, however the WD-II is not stressed or balanced for engines weighing over 25 LB.

FUSELAGE AND BOOM

Two sheets (4' x 8') of 1/8 inch Mahogany Plywood were adequate for all of the airplane construction. The first step is to mark out the outlines of the sides of the fuselage, as shown in Dwg. 102. Note that the 4 ft. sheet width just fits between the aft edge at both the engine and the tail boom, and the splice joint at Fus. Sta. 93.0. The two sides were trimmed, then final layout lines cut on the band saw with both sides cut at the same time. The side skins forward of the splice joint were then cut out. The 2.0 inch wide splice 102-33 was glued in place over the inboard side of the splice joints using "C" clamps to hold them in place while drying. Epoxy Cement was used for all basic fuselage wood bonding. Care was taken to assure symmetry between the two sides of the fuselage.

All critical reference line lines, (water lines and fuselage station lines) were laid out on the outside of each fuselage side piece (102-2). A scribe or pointed tool can be pushed thru the 1/8" ply to transfer ref. points from the outside to the inside face. The rectangular holes for the wing spars were cut next. Care was taken to align the two side pieces. The 1/2" square pine stringers and longerons were then glued to the side panels. Small nails (Brads) were used to hold the 1/2" square pieces in place while the glue dried. 3/4" spacing between nails was used to assure clamping pressure at the glue joint.

The bulkhead plywood and filler block pieces were glued separately as individual assemblies. The two skin side panels and four bulkhead assemblies were then glued together, taking care to hold alignment. The 1/2" square pine cross pieces were then glued in place. The next step was to cut, fit and glue in place the following pieces in the order shown:

- No. 102-4 Front Skin
- 102-3 Rear Skin
- Note that these skin panels overlap the side skin panels except where they run inside of contour.
- 102-6 Skin
- 102-11 Seat
- 102-9 Deck
- 102-10 Face
- 102-14 Bottom
- 102-19 Face
- 102-26 Bulkhead

The wing support cables were installed by cutting the required clearance holes in the fuselage skins and bolting to the bulkheads or control Quadrant. This must be done prior to filling with foam because there is no access. The foam tends to secure the cable end fittings.

The Engine Mount (102-22) was fabricated and installed next. The 1/2 inch plywood was selected for hardness and freedom from irregularities. Epoxy bonding was used to secure the (102-21) aluminum faces.

Clamping pressure at the bond joint should be evenly applied. The aluminum surfaces to be bonded were prepared by scrubbing with an abrasive powdered cleanser such as Ajax or Comet. Making sure all surfaces to be bonded were dull from scrubbing. A clean cloth was used, not touching with bare hands or contaminating in any way. After scrubbing, the surface was washed with water and checked for surface wetting continuity. If beads of water tended to form on the aluminum surface, scrubbing was not sufficient. After wetting with water, a continuous thin film of water should remain. After this check, the surface was dried with a clean cloth. The two parts of the epoxy were then mixed thoroughly and spread evenly on the aluminum surface to between .010 and .020 in. thick. The wood face of the engine mount plate was then bonded to the fuselage using epoxy glue. The (102-26) bulkhead was installed and the 7/8 inch steel prop shaft installed per drawing 108.

The (105-16) Tail Boom assembly was made up next. The first step was to bond on the (105-17) doubler, as shown in Dwg. 105. The same epoxy bonding and cleaning process was used except that 3" Dia. hose clamps were used to obtain bonding pressure. In this case the end of the boom was inserted into a kitchen oven set at 150° F. for one hour. The tail boom was then cut to length and flattened at one end for attachment of the horizontal tail piano hinge. The tube was filled, locally near the rudder tube location, with balsa wood to reduce flattening at this point, a common bench vise was used to form the tube. The (105-14) and (105-15) aluminum doublers were then riveted to the boom assembly with either "cherry" rivets, or Pop Blind Rivets. The vertical hole for the rudder tube was then drilled in the boom for a press fit with the bronze bushings. Epoxy glue was applied prior to installing the bushings. The forward half of the (105-18) horizontal tail hinge was then riveted to the flattened aft end of the boom.

The aft bulkhead, (102-23) was then installed, with the hole mated to the forward end of the boom. The (102-25) bulkhead was fitted to the boom and the boom inserted in the aft fuselage. The (102-25) bulkhead was bonded in place with epoxy glue after the tail boom was aligned with the fuselage.

The control torque tube and elevator cable guide tubes were then installed per Dwg 106. The next step was to fill all possible spaces within the fuselage with Isofoam mix. 3/8 inch thick sheets of styrofoam (which will not melt in contact with Isofoam) was used to seal off portions of the fuselage over the control torque tube so that it would not be filled with foam in this space. Tape was used to hold the styrofoam in place while the Isofoam was being poured. **CAUTION** was taken to pour only a small amount at a time to avoid internal pressure build up during foaming. The fuel tank was held in place with temporary supports until the foam was poured.

The foam was allowed to build up outside of contour and was trimmed with a saw after hardening. After sanding the foam flush with the edge of the side faces, the rest of the 1/8" plywood skins were glued on with epoxy cement. Tacks were used to hold skins in place. The (102-6) upper skin was cut out to clear the fuel tank opening. The (102-7) bottom skin should be left off until all of the controls and landing gear are installed. The (102-20) rudder peddle foot rest, (102-18) throttle support, and (102-21) seat belt attachment bar were installed next. The (102-27) engine mount reinforcing gusset was then glued in place with epoxy cement.

WING PANEL CONSTRUCTION

The wing panels were designed for simplicity, ease of construction and low weight. Rapid and simple attachment to the fuselage was also a prime consideration. Some compromises to traditional appearances were made, however the resulting wings have reasonable pleasing lines and seem to function well, both in flight and in ground handling. Wing warping was employed on both upper and lower wings for roll control so as to eliminate ailerons. A single hand formed aluminum tube is used for each rib. The one piece front and one piece rear wooden spars are assembled into a rigid lattice, with simple pine spacers and diagonals. The wings are assembled to the fuselage by simply inserting the root ends of the wing spars in holes in the fuselage. Flying and landing wires are then connected and tightened with turnbuckles. The tension from these wires holds the wings in place. The rear flying and landing wires (cables) are shortened or lengthened to achieve wing warping.

The first step in construction was to cut out a 30" x 72" piece of 3/8" plywood to use as a wing jig. The wing station lines were drawn normal to the spars at wing stations 4, 14, 24, 34, 44, 54, and 64. The outlines of the (104-6) spreaders and (104-7) diagonals were then drawn in. The same layout was used for both upper and lower right wing panels.

The next step was to shape the spars. A circular saw was used to trim the spars to the cross section shown on Dwg. 104. The rib center line locations were marked on all eight spars at the same time to assure symmetry. The outboard end of the rear spar (104-3) was cut to length and tapered as shown. The next step was to drill the 3/8" diameter holes in the front and rear beams for the wing ribs. A simple drill jig was made by making a wood box with cut outs that fit the cross section of the spars. The cutouts were made to position the spars at the proper angles for drilling.

All holes were drilled for a loose fit with the (104-8) rib tubes. After the spars were drilled, they were ready for assembly with the spreaders and diagonals. The spars were held in place on the plywood jig with "C" clamps. Holes can be cut in the plywood jig to get the clamps in position. The gussets, spreaders and diagonals were then cut to fit. The (104-7) gussets used on the top of the (104-6) spreaders were glued to the (104-5) nailblocks prior to assembly. The top gussets, spreaders and diagonals were all joined by glueing with epoxy cement. Small nails or brads were used to hold the assembly in place. Not over 3/4 inch nail spacing was used. The whole wing frame was then un-clamped from the jig and turned over. The bottom (104-7) tip spreader (102-6) at wing station 94.0 was installed in the same manner. The (104-9) and (10) strut and cable attach fittings were then bolted in place.

The (104-8) wing ribs are all identical. A simple bend fixture was made by laying out a full scale rib on a piece of 3/8" plywood. A second piece of 1/8" plywood was glued on so that it could be used as a form block to bend each rib to the same shape. A short socket was provided at the front end to hold the tube in place while bending around the form block. There was a large amount of spring back and it took several trial cuts in the form block to get the finished curvature to match the desired shape. Note that aft 14 inches of the rib tube is left straight. The ribs were then inserted thru the holes in the rear beam and pushed into the holes in the front beam. The tip bows are made from the same tube stock as the tips. These were formed by hand bending to a smooth curve that is flat on the bottom between the spars, but is bent downward to be in line with the trailing edge of the ribs. The (104-12) clip was then bent around the rib and screwed to the aft spar. A 3/8" hole was drilled in the front spar to provide support for the front of the tip bow. The aft end of the tip bow was attached to the outboard rib with cloth tape.

The leading edge of the front spar was faired in with strips of 3/4" rigid urathane foam (2.0 lb. per cubic ft. density). Epoxy cement was used to bond the foam to the leading edge. The foam was then sanded to form a smooth surface, matching the desired leading edge contour. A coating of epoxy was then applied to the surface of the foam to give a hard surface.

The wing panels were then mated to the fuselage. Some hand sanding was required to get the wing spar root ends to slip into the holes in the fuselage. Note that no bolts are required to hold the spars in place. The flying wires hold them tight to the fuselage.

The next step was to apply the wing covering. The upper surface extending from the lead edge to the trailing edge is installed first. A seam is made at the trailing edge. The (104-13) fabric recess is sewn to the trailing edge prior to glueing to wing. A colored light polyester fabric, normally used for coat lining, was used. A light dacron or grade "A" cotton glider fabric could have been used. The fabric is applied by hooking the trailing edges in to the -13 recesses and drawing over the leading edge where it is glued in place with nitrate dope. The tip and inboard rib are also glued to the fabric. 1/4" wide cotton "Rib Stitch Tape" is then glued to the fabric over each rib. Cotton chord rib stitching is then wrapped and tied at 2.0" spacing over the front half and 4.0" spacing over the rear half of each rib. (See CAM 18 for typical rib stitch details). The lower surface can then be glued in place.

After the fabric is on, the dope can be brushed on. Only enough dope was used to fill the pores in the fabric. The wing must flex for wing warping control, but the small holes in the fabric must be completely filled to avoid loss of lift. To keep the dope flexible, about one ounce of castor oil was added to each quart of nitrate unthinned dope. Thinner was added as required for brush application. Only clear dope was used.

HORIZONTAL AND VERTICAL TAIL

The 1/2" Foam Sheet covered with light weight fiberglass cloth is the primary structural material for both the horizontal and vertical tail flying surfaces. It is reinforced locally with 1/8" plywood and is strut braced to carry the horizontal tail bending loads. Very light weight fiberglass cloth (2 oz. per sq. yd. or less should be used to cover both sides of the foam. A minimum of epoxy should be used to glue the cloth in place. Squeegee out all excess epoxy. Cut out foam parts with excess material so that they may be cut to final dims after the glass/epoxy skins have hardened.

The horizontal tail is "One Piece", hinged directly to the flattened aft end of the tail boom with a 6 inch long strip of piano hinge. The vertical tail is made up of a conventional fin and rudder. The rudder is hinged to the fin with a series of interlaced cloth hinges, as is commonly used on model airplanes.

The first step in construction is to draw, or layout, the outlines of the fin, rudder and horizontal tail. These can all be taken from one sheet of 1/2 inch, 4 ft. x 8 ft. foam.

The foam and fiberglass sheets are easily cut with a band-saw or sabre saw. The exposed edges are streamlined and protected by first crimping as shown in Section B-B of Dwg. 105. 1/2 inch square and 1/2 inch "half round" pine moulding pieces were inserted into the edges that were subject to crushing. This was done by simply scraping out the foam between the faces and glueing in the 1/2 inch pine pieces. (105-11 and -13). Several light spray can color enamel coats were applied to finish the surfaces.

ALTERNATE TAIL DESIGN PER DWG. 105A

Build up structure using 1/2 inch square pine sticks and 3/32" Ply Doublers at joints. An alternate Dwg (105A) is included. Only the revised dimensions are shown. All other dims are per Dwg. 105. The covering is either model airplane silk, or light weight glider cloth with acetate or nitrate dope.

CONTROLS COMPONENT CONSTRUCTION

The three axis of control, pitch, yaw and roll, are accomplished with conventional pilots controls. Namely, a control stick for pitch and roll control, and rudder peddles for yaw control.

PITCH CONTROL

Forward and aft motion of the stick results in differential motion in a pair of 1/16 inch cables tied to horns located at the bottom of the stick. (106-18 and -19). The cables are routed over pulleys and fed thru flexible guide tubes to the aft bulkhead in the fuselage. The cables then are routed along side of the tail boom and are connected to horns located at the horizontal surface hinge line. Each cable incorporates a turnbuckle to adjust tension and to center the stick. The horizontal surface is an "all flying", or one piece tail, hinged at the 30 percent chord.

ROLL CONTROL

Lateral motion of the control stick rolls the (106-2) torque tube, rotating the quadrant cable drum at the inboard ends of the lower aft flying wires. The differential motion of these flying wires (cables) causes the rear beam to twist up or down in response to control stick motion. The front beam is held rigid by the front flying wires so that the wing panels warp, or change incidence for roll, or lateral control. Turnbuckles on the flying wires are used to adjust cable tension, stick centering, dehederal and wash-out.

YAW CONTROL

Conventional rudder peddles are used to control rudder action and tail wheel steering. 1/16 inch cables extend aft from horns on the rudder peddles. These pass on either side of the fuselage and along side of the tail boom to connect to fittings on the rudder torque tube horns. This torque tube (106-26) extends upward to actuate the rudder and downward to support the tail wheel. The control cables are fitted to the proper length on installation to avoid the necessity of turnbuckles.

CONSTRUCTION

4130 Steel in the normalized, or condition "N" was used for the stick, torque tube, and tail wheel support components. Brazed joints were used thru out, however welding would have been O.K.. Cable thimbles and Nico-press sleeve fittings were used at all cable ends. 18-1-G Nico-press sleeves for 1/16 inch cables and 18-2-G for 3/32 inc. cables. Double Nico sleeves were used on all lift flying wire cable ends. AN115-1 shackle fittings were used with AN100-3 cable thimble

fittings at all control horn attachments. At wing spar fittings, attachment to flying wire turnbuckles (See detail on Dwg. 106) shackle fittings were spread apart to straddle the 104-9 and -10 fittings. The thickness of the AN115-8 shackle fittings were filed down so that they would fit in the turnbuckle clevis ends. The use of a shackle is essential at the flying wire ends to avoid putting bending stresses on the turnbuckle end fittings when the wings are warped. A fitting failure was encountered prior to the use of shackles at the cable joints. Cable fairlead, or guide blocks were provided for elevator and rudder cables at a point about halfway back along the tail boom.

LANDING GEAR ASSEMBLY

Drawing 107 shows the details required to fabricate a laminated wood spring type main landing gear strut. A covering of fiberglass cloth impregnated with polyester resin, is used to strengthen the laminated wood which is also bonded with polyester resin. Since there is a wide variation in the spring properties of wood, additional layers of glass cloth may have to be used to obtain the desired landing gear stiffness.

The first step in construction is to rip cut the selected wood stock into 1/8" thick laminations by 4" wide. A hollow ground 10" diameter blade should be used, (3" plus 1" strips may be butt joined in staggered laminations). A holding fixture will be required to bond the laminations in the proper shape. About 2° was allowed for deflection to the static position shown on Drawing 107. Since there is only one bend in the strut assembly, a simple fixture was made by cutting a 5.88" radius female notch in a 4 x 4. A 4.0" radius male piece was also cut from a 4 x 4 with a flat surface so that it could be clamped to the female piece with large "C" clamps. An initial set was given to the laminations by soaking in water, then clamping in place until dry. Plyofilm was then placed over the fixture pieces (to avoid sticking) and the laminations were coated with the polyester resin mixed with hardener. The whole lamination assembly was then clamped in place for bond curing. Care was taken to use a slow hardening polyester mix to avoid premature set-up. After the initial forming and glueing, the 107-5, -6 and 107-12, -13 pieces were bonded in place. The final shaping was then done to fit the strut assembly to the airplane and to give it a streamlined shape as shown in 107, Section B-B. The fiberglass cloth was then bonded on all over with polyester resin. The 5/8 inch hole for the axle was drilled with a 2° chamfer and no toe-in. The axle was bonded in place with epoxy glue. After the 1/4" holes for the mounting bolts were drilled, the gear was ready to install.

LANDING GEAR NOTES

An alternate to the Dwg 107 laminated wood landing gear is enclosed. This landing gear used 5/8 dia. x .028 wall 4130 steel tubing, and 3/8 dia. rubber shock chord. The basic dimensions are the same as 107. The six loops of shock chord should be tightened until the vertical tubes are firmly seated against the hardwood stop blocks with the maximum weight pilot seated.

Flattened tube ends are shown as pivots, however rod end bearings could have been used if the empty weight of the total aircraft is per specs.

POWER PLANT INSTALLATION

The heart of the WD-II Biplane is the McCulloch Model 101A or 101AA Engine, developed for competition "Go-Kart" racing. This is a precision well built little engine that weighs about 12 lb., and puts out between 12 and 15 HP on plain fuel, without exhaust tuning. Flight tests to-date have indicated very smooth reliable operation at various altitudes, with none of the step function changes in power with throttle change usually associated with two stroke engines. This engine should be available from any local "Go-Kart" shop as well as the following:

Pull Starter Kit

Power band Belt No 2/3V265 (26 1/2 inch long double "V" Belt)
acquired from:

GATES RUBBER CO.
999 So. Broadway
Denver Colorado 80217

Two matched "A" size std. (Auto) "V" belts of the appropriate length will also work O.K.

Exhaust Stack - Cowbell No. 1853

Throttle Bracket

Throttle Cable End

Throttle Cable (6 1/2 ft.).

Throttle Twist Grip (3/4" Bore)

Fuel Oil Lub. (Qt.)

*Cylinder Head Temperature Gage E.M.S.

*Extra Large Carburetor WR33

Woodruff Key (Spare)

Wheels and Tires (Dwg. 107)

* Optional Items (Not essential)

The tachometer is not essential but is handy. It is an electric version powered by the engine magneto. 0 to 12,000 RPM range is available from:

WESTBURN MFG CO.

3400 Westach Way

Sonoma, California 95476

Telephone: 707-938-2121

Be sure to state that the Tach. is to be used on a McCullough 101A, (101AA) Engine because it requires a special hook-up.

A magneto kill switch (ignition) was mounted on the (102-10) fuselage face skin with wires extending along the throttle cable to the engine. Mystic cloth tape was used to hold the throttle cables and switch wires in place on the side of the fuselage. A pulley was added to the pull starter so the nylon cord could be pulled from the seat area.

PROPELLER

The propeller shown on the ref. Drawing 109 is the third in the series that was constructed to optimise diameter and pitch ratings.

The first step in prop fabrication was to obtain the material. I was able to obtain quality beech wood planks at a local lumber yard. This material is similar to birch but has less tendency to split and less grain definition. It is very tough and cuts clean. The lumber yard milled these planks down to the finished thickness for a nominal cost. It should be noted that lamination lines are excellent contour indicators and that the thinner thicknesses provide more lines for contour checking. After cutting the planks to lengths and widths of about 0.50 inches over finished dimensions, glue the laminations as follows. The big problem here is to find a flat surface that you can lay the laminations on and still have access for clamping. Using the size clamps available, the Whing Ding prop was glued on a select, dried one inch fir back-up surface. This was covered with wax paper and the laminations were layed on, one at a time. Weldwood casine glue was liberally applied to both sides of each lamination. If the atmosphere is dry, it is good practice to "Paint" the surfaces with water prior to application of the glue. It takes some time to do all the glueing and lay-up before completion of clamping and the glue could dry prematurely. One word of caution: A rough balance check of the individual laminations should be made to preclude getting all the dense or heavy ends on one side. After glueing the laminations, a pair of angle iron pieces may be placed on top of the laminate stock to help distribute clamping loads and to keep the work piece straight. Use many "C" clamps to obtain required glueing pressures. Required clamping pressures are on the order of 50 lb. per sq. inch, so weights are impractical. Weldwood glue should be used in a warm room and should be allowed to dry for 12 hours or more.

After removing the laminated prop blank from the "C" clamps, a first bandsaw cut can be made after a plan layout is made. Drill a small hole through the hub center to use as a reference. The diameter line is then drawn thru this reference. Blade station lines are drawn normal to the diameter lines, and the leading and trailing edges are established parallel to the diameter line. The hub circle is drawn and the leading and trailing edges are faired to the hub with a French Curve. The prop blank is then cut to the plan form on a bandsaw, being careful not to cut into final material. The cut surfaces should then be sanded or planed to provide reference surfaces. The important thing here is that the two blades are identical about the diameter line. The working radius station lines can then be drawn on all four sides. These stations can be selected at any set of points. I use 10 percent radius increments.

The next step is to mark the contour of the back side surface intersections. At this point I made a simplifying compromise that turned out to be a work saver, by keeping the trailing edges at the back corners of the prop blank and simply marking off the leading edge

Offset resulting from the pitch angle at each working station. A faired line is drawn between the hub and this leading edge line at a point where we run out of thickness. A faired line is also drawn between the hub circle and the trailing edge corner.

The next step is to remove the material between the trailing and leading edge lines, leaving a twisted surface with straight line elements at each station. I use a bandsaw to remove most of this wood, however this must be done with caution and is not normal practice because of the twist involved. A large tooth rip saw blade with as much tooth offset as possible is a big help. After cutting both blade back sides, a trueing to final contour is quick and simple using a wood plane. Relative blade contours should be checked against lamination lines. After the rough cuts on the upper surface, I clamped a "2 x 4" in a vise and "C" clamped the blade to the "2 x 4" at the hub. This put the prop in a good position to apply the quantities of elbow grease that were to follow. Hand working with a wood plane, hand rasp, and spoke shaver is not too difficult after most of the material is removed by bandsaw operations.

At this point the station line markings (most of which were cut off) should be marked on the finished back side of the blade for contour reference. I also use a dark colored felt marker pen to color the trailing edge, which is cut down to about 0.04 inches by hand working. Without this color differential it is hard to judge trailing edge thickness. Both blades should be worked down to the maximum section thickness shown on the drawing for each station. If the plan form of the blade is to be reduced at the tip, now is a good time to do it. Identical cuts should be made on each blade relative to the diameter line. I used a disc sander for this operation. The next step is to contour each station upper surface to an airfoil cross section. So long as the point of maximum thickness is near the diameter line (or plane thru the hub center line), the variations in shape do not appear too critical. However, the leading edge radius and the trailing edge thickness should be as small as is consistent with desired ground handling. The actual airfoil sections used was a modified Clark-Y with thickened portions near the leading edge. The important point is that the two blades match each other. Close comparison of the lamination lines is the best guide. A wood chisle and mallet are handy for working out the material near the hub where the airfoil sections blends into the cylindrical shaped hub circle. A final hand sanding is used in conjunction with "feeling" the surfaces for irregularities.

A quality, high speed steel hole cutter should be used on a drill press to bore out the 1 7/8" hole in the hub. After the hub is bored out, the prop should be balanced. This is done by inserting a short rod in the hub and resting it on a level surface. Hand sanding near the tip is very effective in obtaining a balance. Several coats of urethane varnish are then applied and the balance test repeated. Any unbalance is then corrected by spray painting the light blade.

RIGGING

Control cables are used to extend pilot effort to the aerodynamic surfaces, which effect airplane pitch, roll and yaw control. In addition cables are used, in Biplane fashion, to carry primary wing loads. The rear wing cables provide roll control, thru wing warping, as well as carrying wing lift, and landing loads.

RUDDER CABLES - These are routed directly from the clips on the rudder peddles, to the horns on the rudder post. They are made up to a length that provides a comfortable angle at the rudder peddles (about 30° from vertical) and should not require adjusting, and remain connected during storage or transport of aircraft. 1/16 aircraft cable is used with AN100-3 thimbles, and AN815 shackle fittings at both ends. "Nico Press" sleeves were used to clamp the cable ends.

ELEVATOR CABLES - Reference drawing No 106. 1/16" aircraft cables are attached to the (106-18 and -19) horns with AN100-3 thimble, AN815 shackles and AN393 Clevis pins. The cables are routed over the front pulley and thru the (106-24) flexible guide tubes. Care was taken to install these tubes and securely tighten the (106-23) clamps prior to filling the fuselage with foam and closing the bottom panel. The cables exit the guide tubes just aft of the (102-23) bulkhead where a turnbuckle assembly is used on each cable. 1/16" cable extends from these turnbuckles to the horizontal tail control horns (106-6). The turnbuckles are used to adjust stick forward and aft position, and to tighten the cables. The horizontal tail is removed without effecting the elevator control cables or their rigging.

ROLL CONTROL - When the control stick is moved laterally, the (106-3) quadrant is caused to rotate. This rotation effects the rear (1/16" cable) flying wires as shown in the rigging sketch shown in the upper left side of Dwg. 106. Turnbuckles are used at each upper outboard connection, however due to the pulley action at the upper center, only one turnbuckle is required in the cable running from the lower outboard fittings. When the wings are removed the upper outboard turnbuckles can remain safetied. The single lower turnbuckle can be loosened to put slack in the whole rear wire system.

WING RIGGING - The front flying wires (3/32 cable) are adjusted first. A turnbuckle is located at the outboard end of each cable. The two lower turnbuckles are tightened until there is a small amount of dihedral in the front beam. (About 1" rise at the strut.) Each wing is adjusted to equal dihedral. The upper turnbuckles are then snugged up. Do not over tighten, but make sure the cable tension is adequate to hold the wing tight. Safety wire was used on all turnbuckles. Only the lower turnbuckles need be loosened for dis-assembly.

The rear flying wires are adjusted to provide a slight washout of the wing tips and to center the stick. About 2° of washout (trailing edge up at the tips) is obtained by adjusting the two upper aft turnbuckles. Cable tension on all aft wires is adjusted with the single lower turnbuckle.

WEIGHT AND BALANCE

The overall empty weight of the first WD-II biplane is 118 lb. This machine was used for design development and has had many modifications and repairs. It is felt that subsequent machines could be several pound lighter. Since no oil tanks or baggage is involved, the only additional weights are fuel (at 3.0 lb for 1/2 Gal.) and the Pilot. Weight and balance checks were made using a calibrated bathroom type scale. The aircraft was leveled by blocking up the tail wheel with the scale placed under either one of the main wheels or tail wheel. Blocks simulating scale platform height were placed under the other two points. Level check was made by dropping a plumb-bob from the upper wing leading edge to the lower leading edges of the wing. Both wing leading edges and the main wheel leading edges are conveniently located at Fuselage Sta. 100.0. The scale was alternately placed at each main wheel and the tail wheel. The conventional moment arm method was used to determine the center of gravity location relative to the Datum Point at Fus. Sta. 100.0. The FAA weight and balance Form (which must be filled out for experimental licensing) calls for an empty weight check with estimated pilot C.G. and moment determined mathematically. This proved to be inadequate for the WD-II because the pilot is such a large percentage of the gross weight, the final balance check must be made with the pilot in place.

CENTER OF GRAVITY LOCATION - The 36 inch wing chord results in 1.0% chord change for each .036 inches change in C.G. locations. C.G. locations too far aft could result in pitch instability in flight, while forward C.G. locations can reduce flight performance. The recommended envelope for gross weight center of gravity locations is 15 to 30 percent of wing chord (5.4 to 10.8 inches aft to the leading edge Sta. 100.0. Styrofoam block or pillows have been used to shift the weight forward with light weight pilots to keep the C.G. within this range. When the one gallon fuel tank or other modifications that moved the empty C.G. aft were used, the pilot was moved forward to keep the Gross Wt. C.G. within the above limits.

WD-II FLIGHT TEST NOTES

PERFORMANCE

All Flight testing to-date has been done at the Mojave, Calif. Airport. The field altitude is 2,700 ft. Air temperatures have ranged from 60° F to 105° F.

Three pilots have flown the WD-II at Mojave with pilots weights ranging from 140 to 175 lb. The maximum pilot weight is 185 lb. The flight data with 175 lb. pilot is:

- a. Landing stall speed - 26 MPH indicated
- b. Cruise (top speed) - 45 MPH indicated
- c. Take off and landing distance - 250 Ft.
- d. Rate of climb not measured, but estimate at 200 to 300 ft.

CONTROL RESPONSE

Control about all three axis is good. Stability appears to be very good. Control loads are very light (with no feed back feel). The maximum height above ground we have flown is about 60 Ft. so we do not know what the stall/spin characteristics are. The power available limits turning bank angles (at constant altitude) to about 20.

XX

WEIGHT BUILD UP

It is tempting to put refinements into the WD-II, but it is amazing how fast the weight can build up. Every little item made more heavy will result in extra pounds to the empty weight. The power available is just adequate for the weights shown.

XX

SPECIAL NOTES

1. Cost - The prototype cost using some surplus materials was approx. \$600.00 incl. engine. However costs of aircraft parts have increased at a rapid rate and no current costs are available.
2. Time to Build - 6 months at approx. 10 hrs per week is average.
3. FAA Approval - The WD-II is treated the same as any homebuilt. It can be certified as experimental, with the same rules that apply to any homebuilt.
4. Sorry we have no kits available

Oct. 13, 1972

CARBURETOR INTERNAL ADJUSTMENT

New, as delivered, Mac 101A Engines with standard fuel carburetors have been found to "Fuel Starve" in several instances. Fuel starving occurs as the engine is accelerated to approximately 6000 RPM at which point it cuts out. Reducing the throttle to idle will pick it up again. The problem is in the adjustment of the fuel pressure regulator arm position. This arm is located in the carburetor fuel chamber nearest the throat. It acts against the diaphragm and a needlevalve that looks like an automotive float valve. The diaphragm end of the lever should be adjusted (bent) to a position .015 to .025 inches above the chamber mating surface. The discrepant carburetors were found to have the arm actually below the mating surface.

LIST OF SUPPLIERS

The following is a list of material suppliers gathered from various publications and trips to Oshkosh. It does not however list every source available, and some suppliers may be more conveniently located to an individual. The best way to locate suppliers is to visit the local phone company office and request to see the yellow pages of the nearest large cities. Shops and distributors of almost any material desired can be tracked down by this method.

LIST OF MATERIALS BY CODE

CODE	MATERIAL
(1)	McCulloch 101A, 101AA, and 101B Engines. <i>OR 101 D</i>
(2)	"AN" Hardware
(3)	Aluminum Tubing
(4)	Aluminum Sheet Stock
(5)	4130 Steel Tubing
(6)	4130 Steel Sheet Stock
(7)	Aircraft Spruce
(8)	Epoxy Cement
(9)	Liquid "Foam-in-place" Urathane
(10)	Rigid Urathane Foam Sheets
(11)	Control Cable and Nico-Press Fittings
(12)	Bearings
(13)	Propellers
(14)	Go-Kart Hardware
(15)	Go-Kart Instruments, Cyl. Head Temp., Tack, etc.
(16)	Aircraft Plywood
(17)	Gates "V" Belt

LIST OF SUPPLIERS

Kendrick Engineering 9520 Defoto Chatsworth, Ca Code: 1, 14, 15	(213) 882-8668	/ B & F Aircraft Supply, Inc. / 6141 W. 95th St. / Oak Lawn, Ill. 60453 (312) 422-32 / Code: 2,3,4,5,6,7,11,16
Pitts Performance Center 7141 Woodley Van Nuys, Ca Code: 1, 14, 15	989-1480 (213) 780-3184	/ All Aircraft Parts / 16673 Roscoe Blvd. / Van Nuys, Ca 91406 / Code: 2
Inglewood Kart Shop 1307 N. LaBrea Inglewood Ca. Code: 1, 14, 15	(213) 678-6811	/ Aircraft Spruce & Specialty Co. / Box 424 / Fullerton, Ca 92632 (714) 525-2611 / Code: 2,3,4,5,6,7,8,10,11,12,16
J & M Aircraft Supply, Inc. 1014 Joseph St., P.O. Box 7586 Shreveport, La 71107 Code: 2,3,4,5,6,7,11,16	(318) 222-5749	/ Flight Line Aircraft Supply Co. / 1201 W. 37th Ave., U.S. 6 / Hobart, Ind. 46342 (219) 942-2215 / Code: 2,3,4,5,6,7,16

Wag-Aero, Inc.
P. O. Box 181, No. Rd.
Lyons, Wisc. 53148 (414) 763-9588
Code: 5,6,11,16

Aircraft Components, Inc.
North Shore Dr. (616) 925-9863
Benton Harbor, Mich. 94022
Code: 2, 11

Tube Sales
211 Tubeway (213) 723-7781
Los Angeles, Ca 90040
Code: 3, 5

Note: Most complete stock of
tubing available - higher price.
Branch offices in nearly every
state in U.S.A.

Tri-Star, Inc.
991 S. State Rd. (305) 792-3460
Ft. Lauderdale, Fla. 33317
Code: 2

Bon Aero
11644 Pearl (303) 452-7141
North Glenn, Co. 80233
Code: 2

Valley Plastics
821 So. Victory Blvd.
Burbank, Ca 91502 (213) 845-3505
Code: 8,9

Wicks Organ Co.
Madison County,
Highland, Ill. 62249
Code: 2,7,8,10,16

Art Air Aviation
850 E. San Carlos,
San Carlos, Ca 94070
Code: 2, 8

Ray Hegy
Marfa, Texas 79843
Code: 13

Banks Maxwell
P. O. Box 3301
Fort Worth, Texas 76105
Code: 13

Classic Air
723 S. Safatoga Ave.
Lakeland, Fla. 33801 (813) 686-1285
Code: 4, 5

XXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXX

Monarch Bearing Co.
4435 Santa Fe Ave. (213) 582-8321
Los Angeles, Ca.
Code: 12, 17

Aero-Crafters Supply
766 Lakebird Ave.
Sunnyvale, Ca 94086
WILL SUPPLY ALL METAL FITTINGS
FOR WD-II

International Paper Co.
Uniwood Fiberglass Laminates
Highway 90, P. O. Box 5380
Statesville, North Carolina
Code: 17

NOTE: TRY ART SUPPLY STORES

Orange County Kart Supply
8016 Orange Thorpe (714) 521-2442
Buena Park, Calif. 90621
Code: 1, 14, 15

19.

NOTE: ALL DIM'S EXCEPT AS SHOWN BELOW ARE
SAME AS #105-2, -6 & -5.

URETHANE FOAM TIPS
(2 LB/CU. FT RIGID)
(OR Balsa)

MAKE ALL GUSSETS
FROM 3/32 (.09) 23 mm
MAHOG. PLYWOOD
3.0" DIA CIRCLES

GLUE ALL JOINTS
WITH EPOXY GLUE.
CLAMP OR TACK
WHILE CURING

REVISED 105-9
DOUBLER

REVISED 105-10
ATTACH FITTING
AS SHOWN

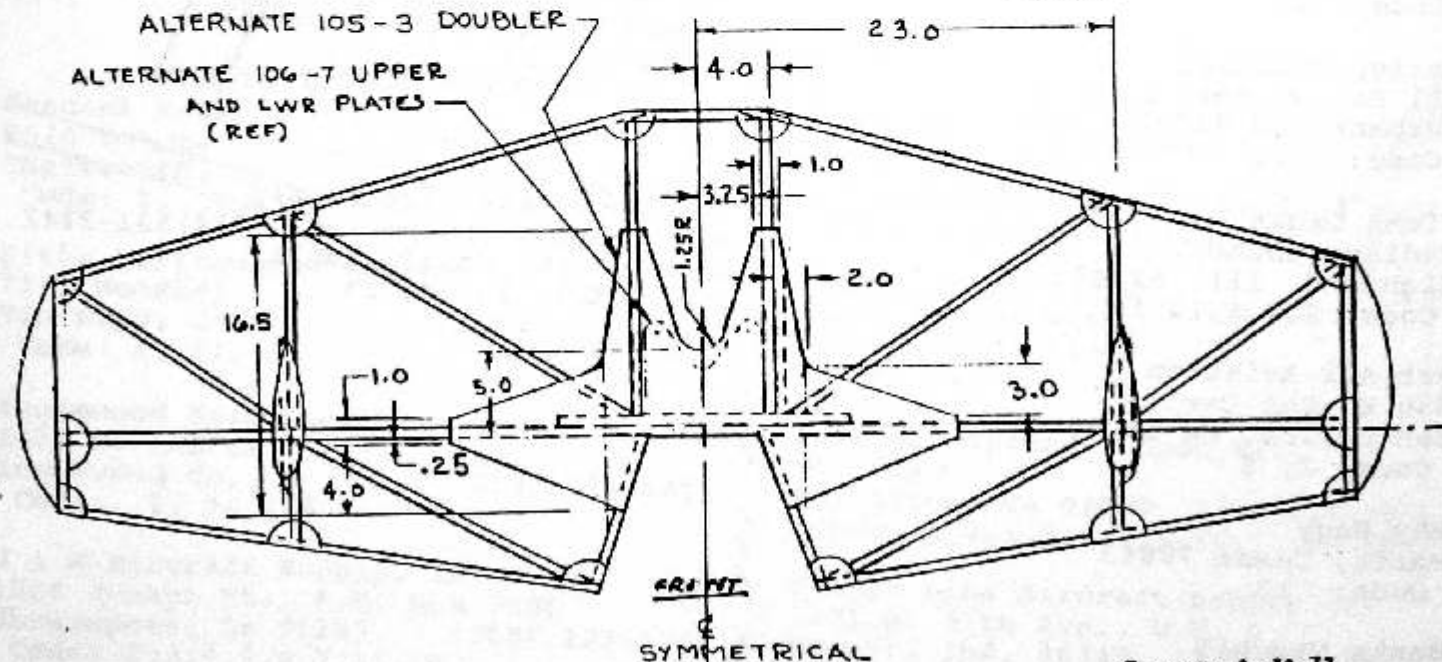
3°
(SAME)

1/2" (.05) SQUARE PINE
STICKS (TYP)

REVISED 105-8 DOUBLER
(1/8)

NOTE:
COVER WITH SILK OR
LIGHT GLIDER CLOTH AND
DOPE.

ALTERNATE 105-3 DOUBLER
ALTERNATE 106-7 UPPER
AND LWR PLATES
(REF)



SCALE
1/10
RUTHVEN
2-12-75

ALT. HORIZONTAL AND
VERTICAL TAIL

REVISED 6-20-77

DWG. NO.
#105A
(ALTERNATE)

MR. MARK
PRESENTED TO ~~MR. MARK~~
FROM: Y.P. SULKHE, INDIA.
V.R.D.E. 071080 AHMEDNAGAR

PN: 414006.
28 FEB 2002

AIRCRAFT SPECIFICATIONS

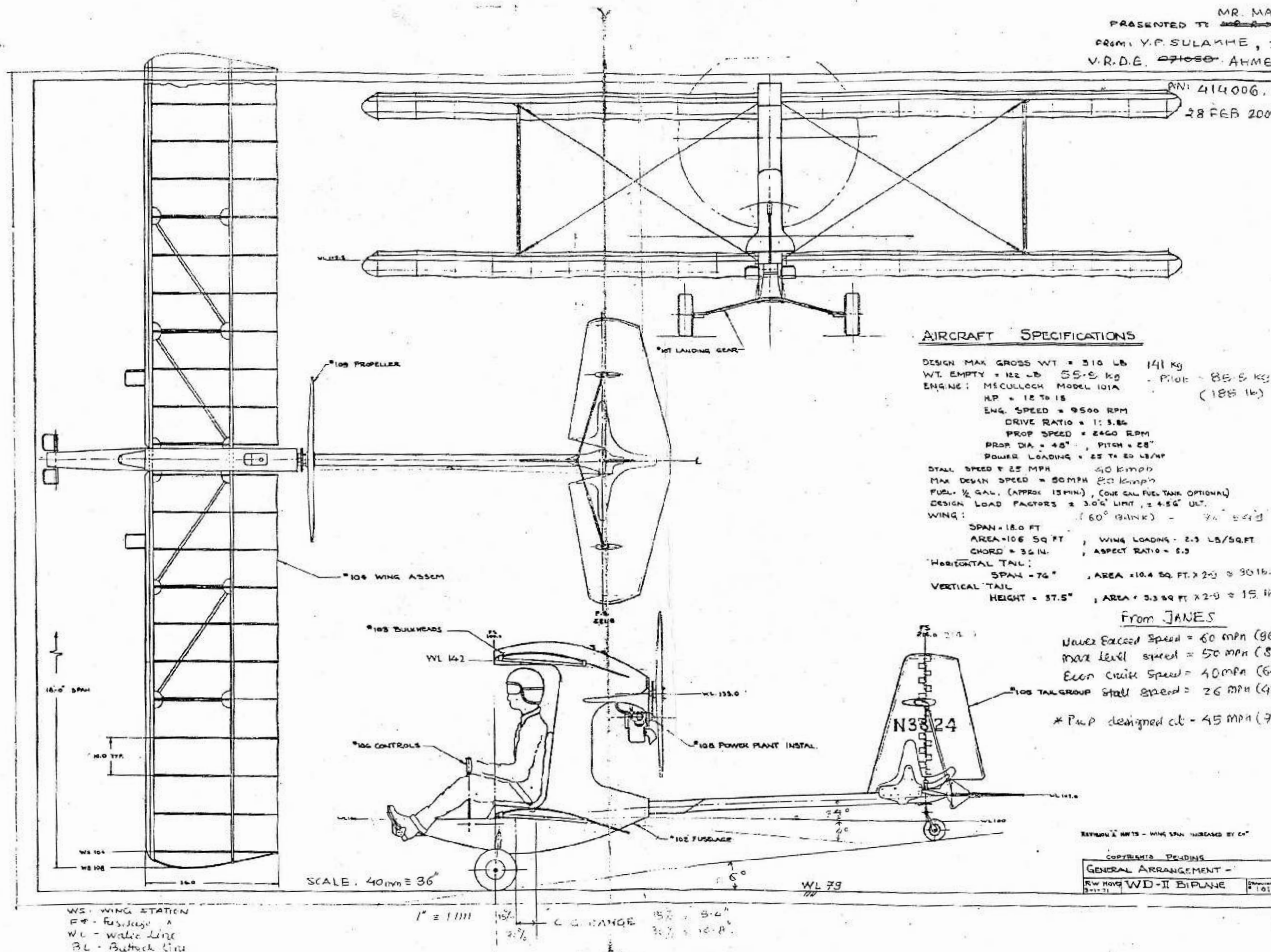
DESIGN MAX GROSS WT = 310 LB 141 kg
WT. EMPTY = 122 LB 55.8 kg
ENGINE: MSCULOCK MODEL 101A
HP = 12 TO 15
ENG. SPEED = 9500 RPM
DRIVE RATIO = 1:3.86
PROP SPEED = 2460 RPM
PROP DIA = 48" PITCH = 28"
POWER LOADING = 25 TO 30 LB/HP
STALL SPEED = 25 MPH 40 kmph
MAX DESIGN SPEED = 50 MPH 80 kmph
FUEL: 1/2 GAL. (APPROX 15 MIN), (ONE GAL FUEL TANK OPTIONAL)
DESIGN LOAD FACTORS = 3.0G LIMIT, $\pm 4.5G$ ULT.
WING: (60° BANK) - 74" 5413
SPAN = 18.0 FT
AREA = 106 SQ FT
CHORD = 36 IN.
WING LOADING = 2.9 LB/SQ FT
ASPECT RATIO = 5.3
HORIZONTAL TAIL:
SPAN = 76" AREA = 10.4 SQ FT x 2.0 = 20.8
VERTICAL TAIL:
HEIGHT = 37.5" AREA = 3.3 SQ FT x 2.0 = 6.6

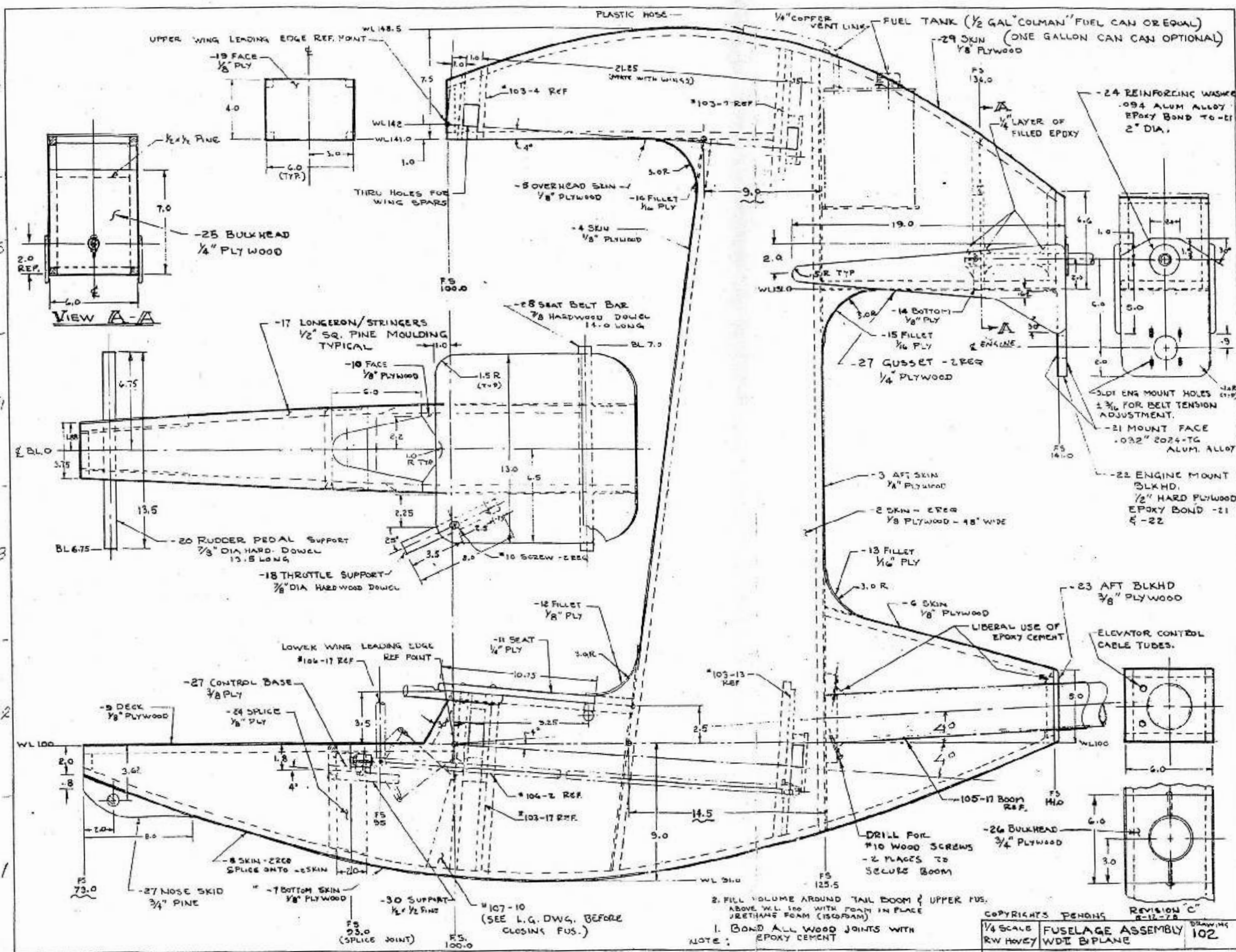
From JAMES

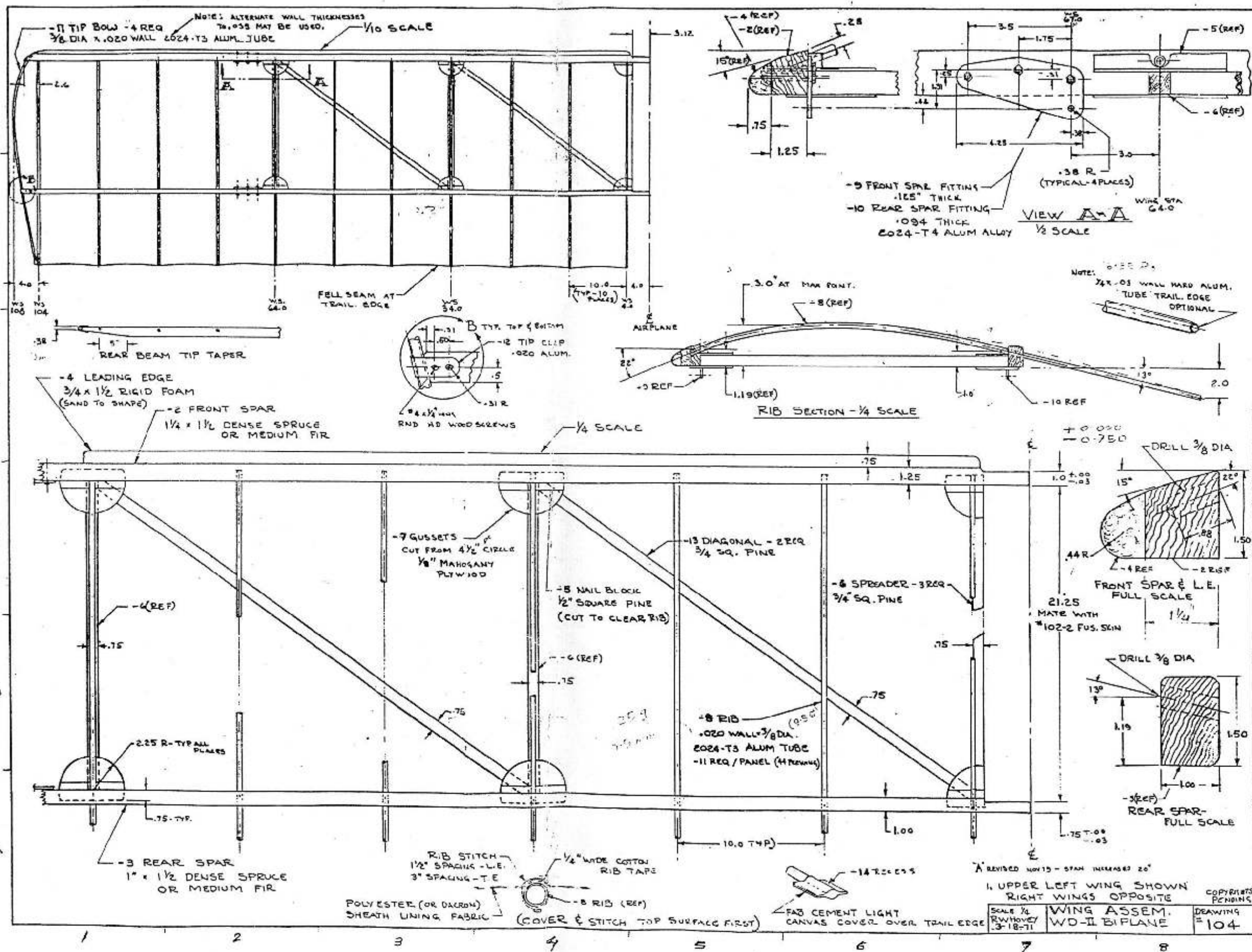
Never Exceed Speed = 60 mph (96)
max level speed = 50 mph (80)
Econ cruise speed = 40 mph (64)
Stall speed = 26 mph (42)
* PWP designed alt = 45 mph (72)

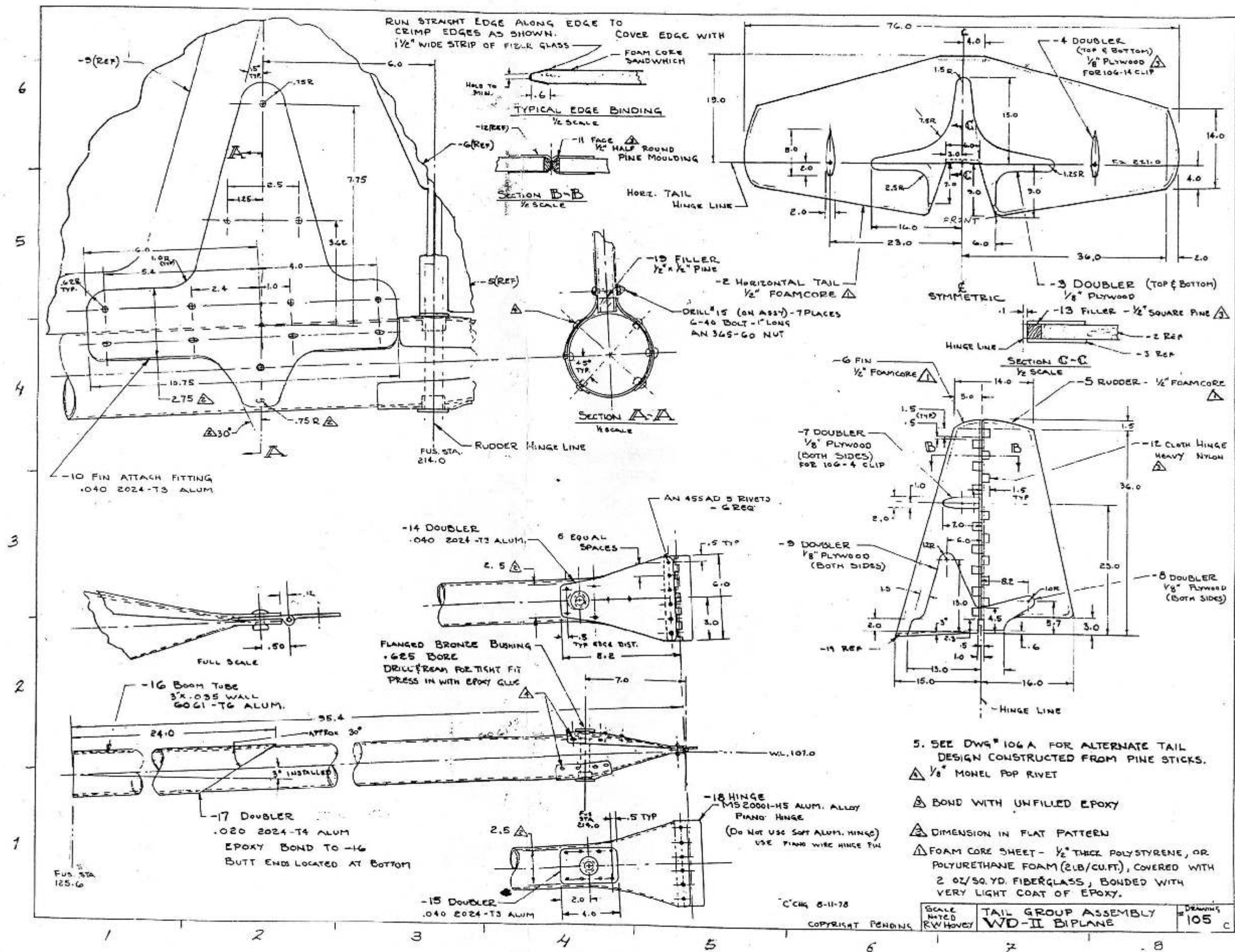
REVISIONS: WTS - WING SPAN INCREASED BY 1"

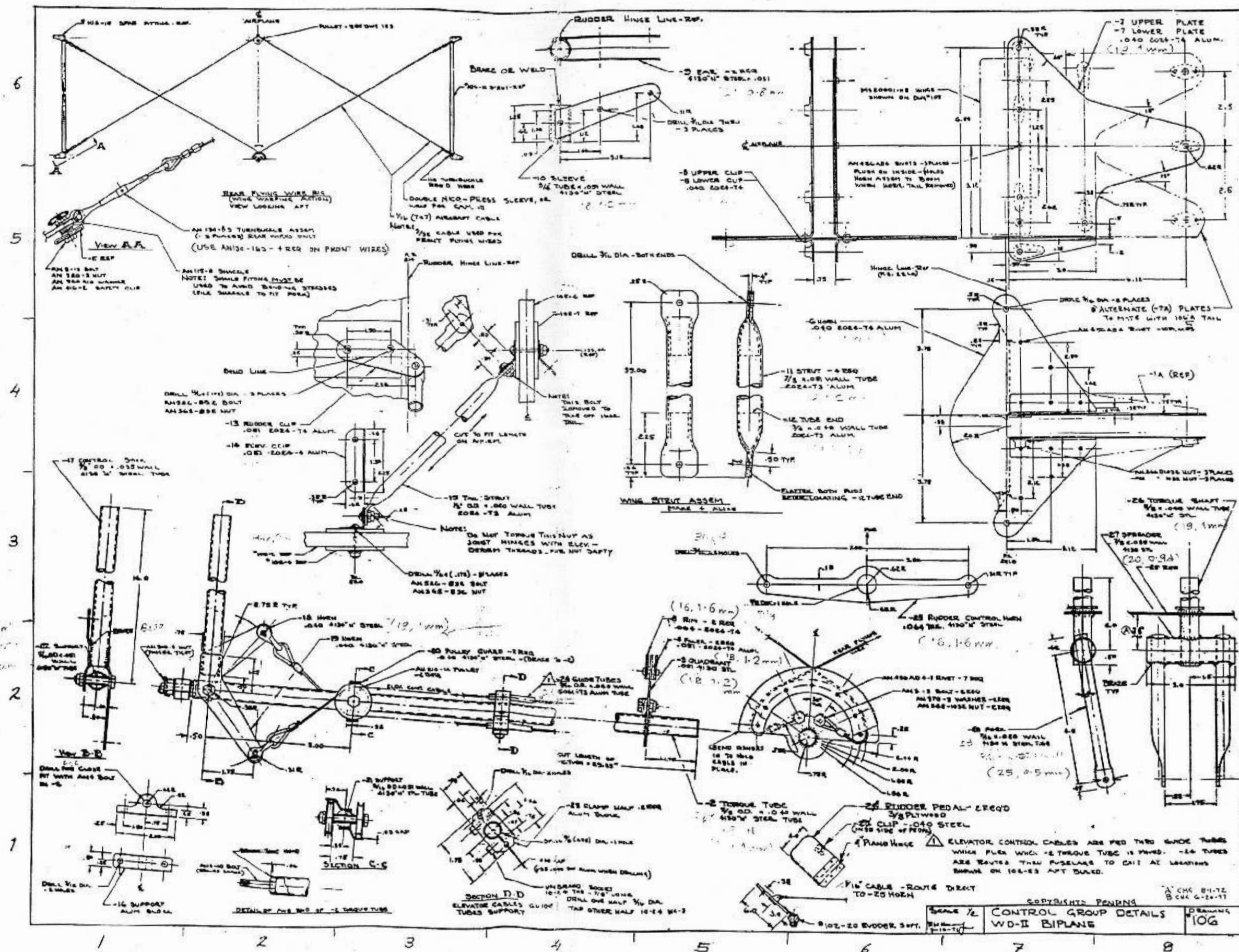
COPYRIGHTS: PENDING
GENERAL ARRANGEMENT -
RW: 1000 WD-II BIPLANE
2-1-11

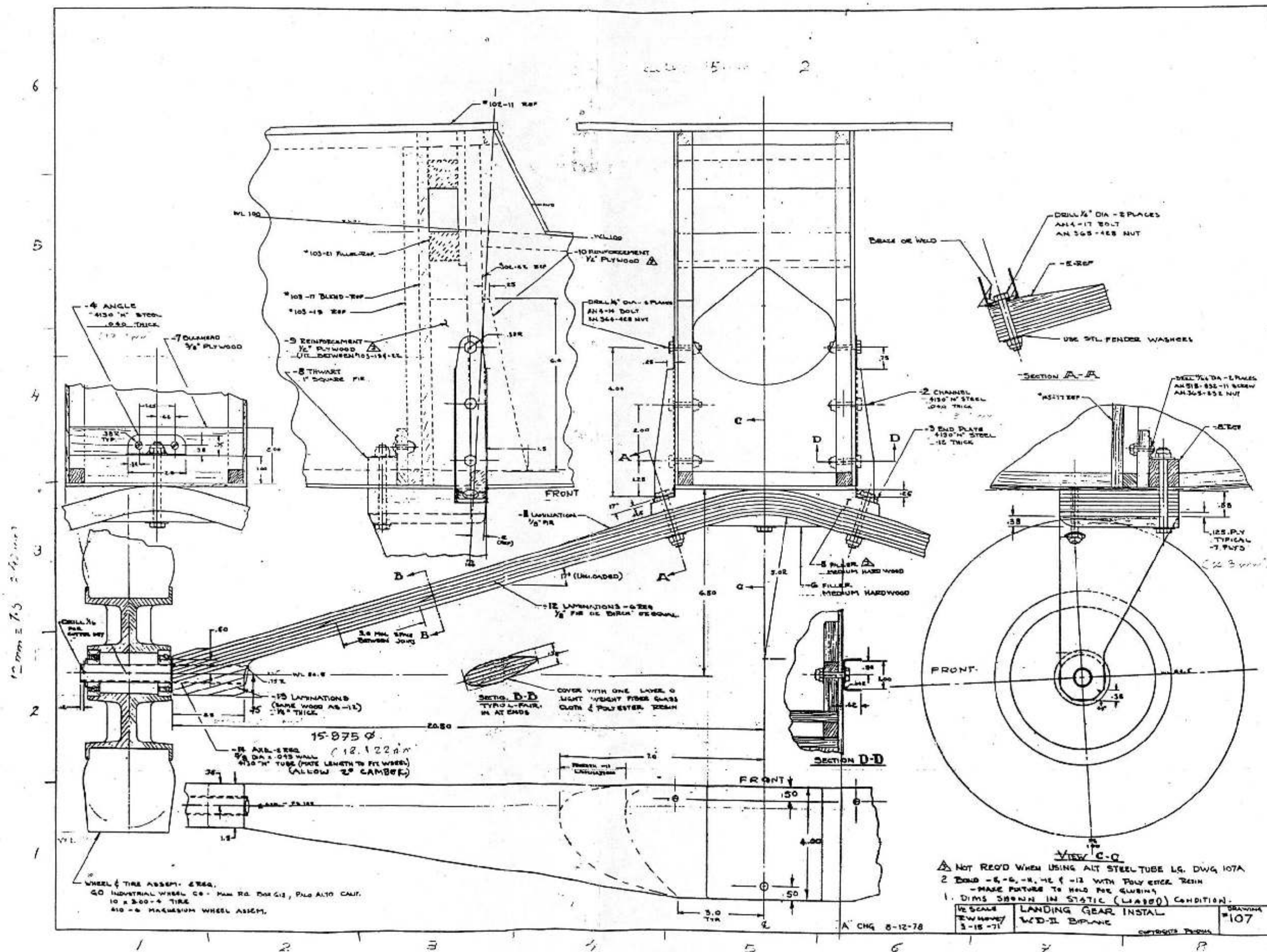


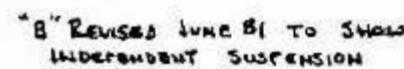
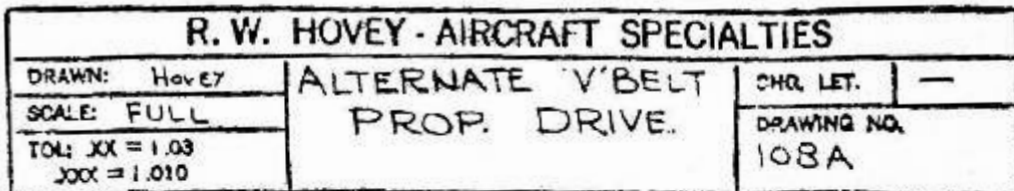






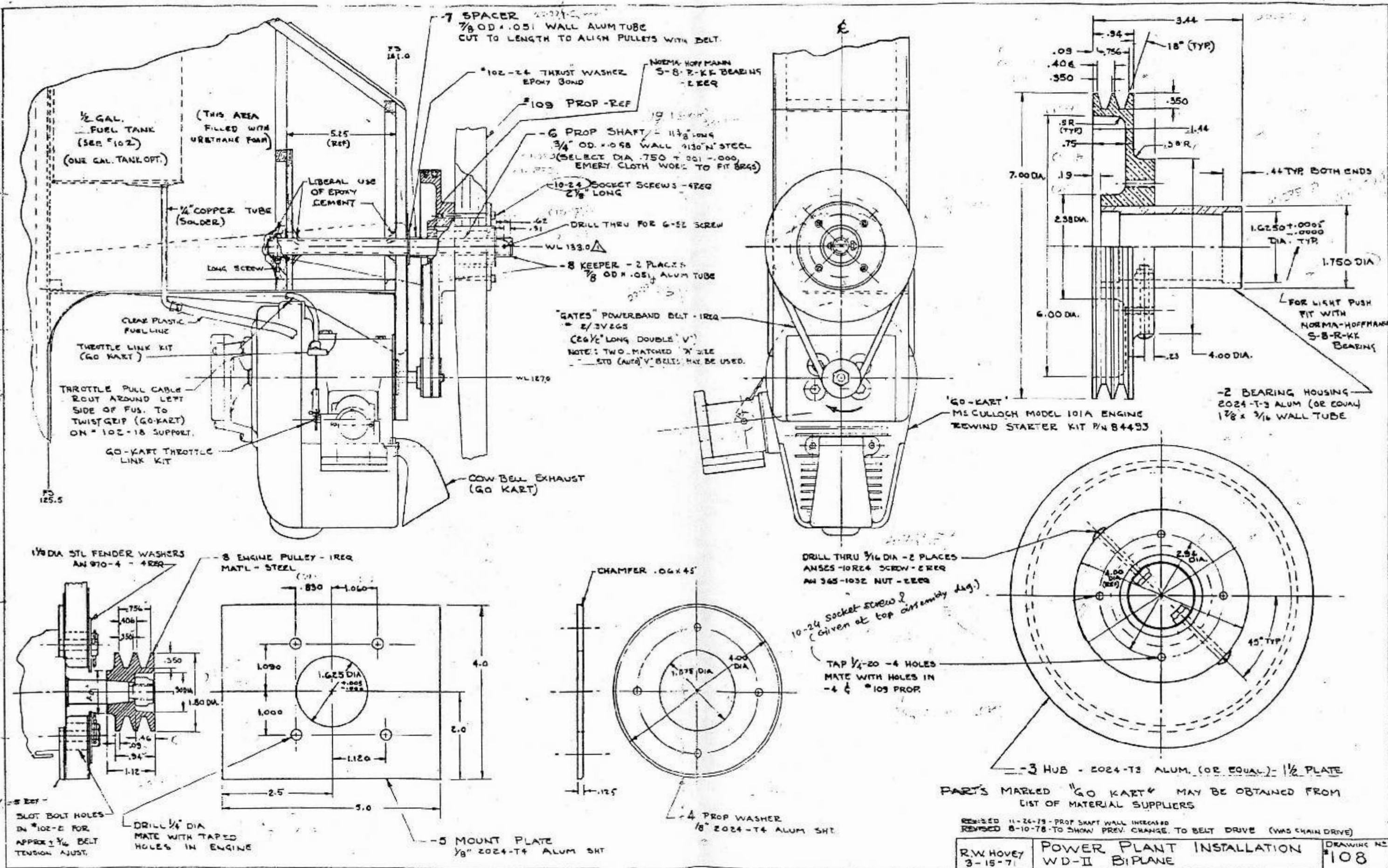


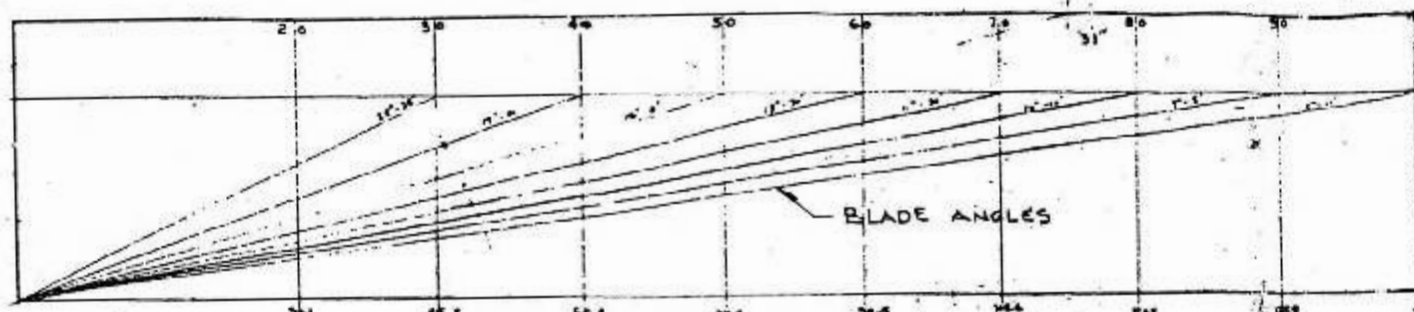




A REV. NOV 79 - AXLE WALL INCREASED.

SCALE 1/5	ALTERNATE STEEL TUBE	DWG. NO.
RWH: <i>Handwritten signature</i>	LANDING GEAR	# 107A
6-72- ☒		(ALT)

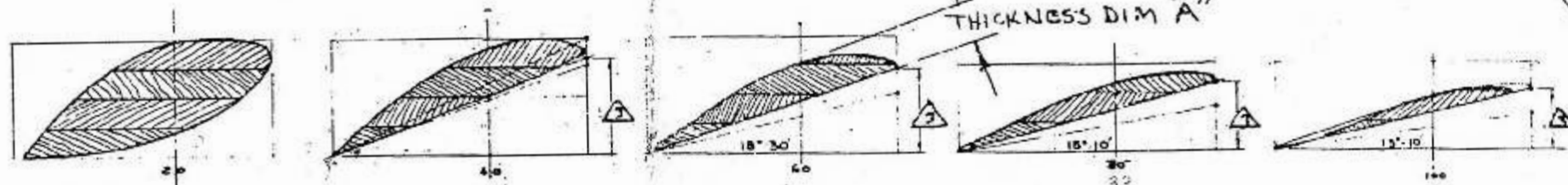
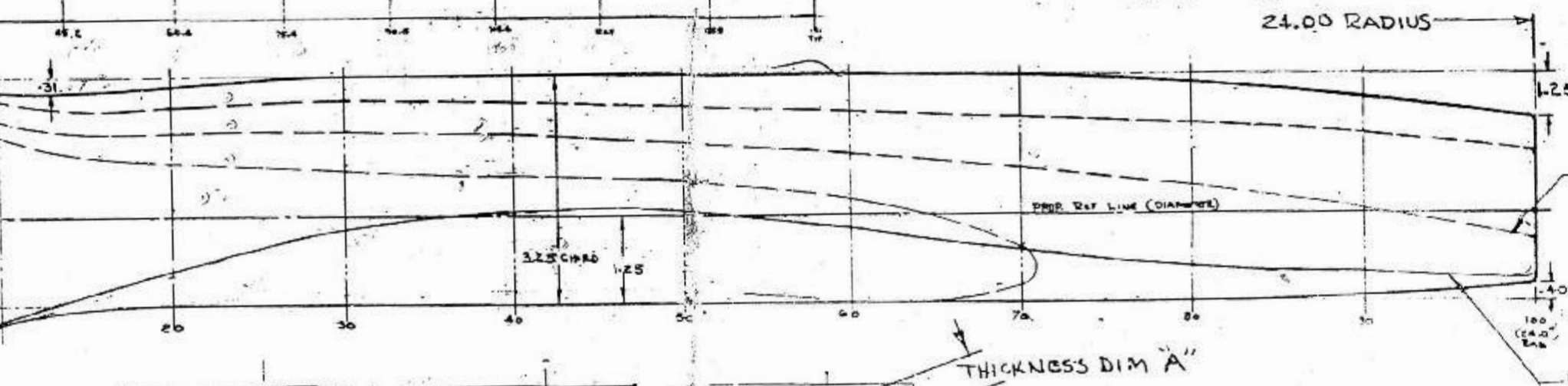
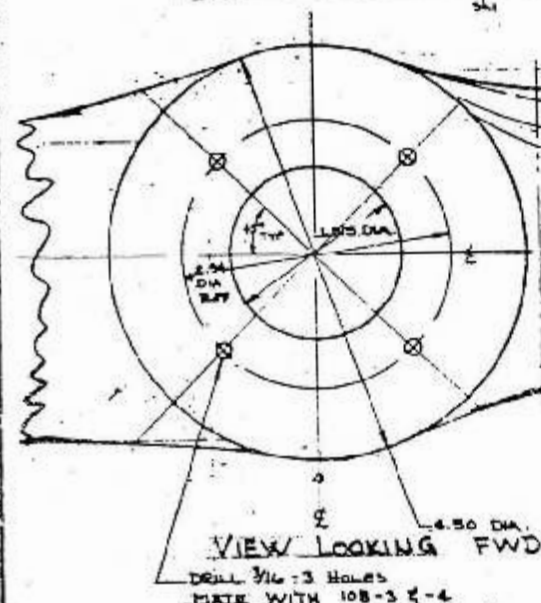




STATION - PERCENT RADIUS		20	30	40	50	60	70	80	90	100
LEADING EDGE OFF-SET FOR 28" PITCH PROP.		1.30	1.120	.962	.841	.760	.695	.640		

FAIR INTO HUB

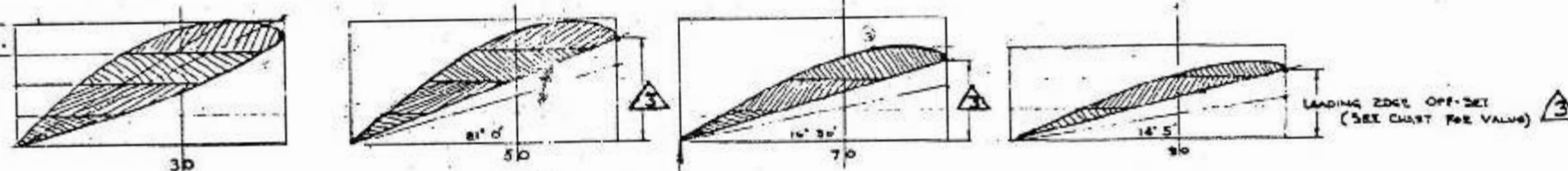
24.00 RADIUS



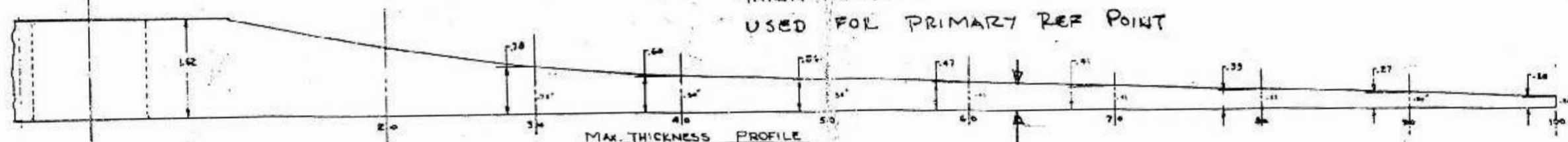
MATERIAL:

USE BIRCH OR EQUAL WOOD
CLAMP BOTTOM SURFACE TO FLAT
BOARD FOR GLUEING

3/8 LAMINATIONS - 4 REB'D.



TAILING EDGE
USED FOR PRIMARY REF POINT



NOTE:

1. ABOUT 50 "C" CLAMPS REQUIRED FOR GLUEING
2. USE WELDWOOD CASINE GLUE OR EPOXY CEMENT

COPYRIGHT PENDING

48" DIAM. PROP. - 28" PITCH
W-D-II BIPLANE

DWG. REVISED 3-6-71
TO SHOW ROTATION
CLOCKWISE
LOOKING FWD

RHOVER
3-16-71

DRAWING
109